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REPORT ON TESTS MADE ON THREE TYPES OF FLUME ENTRANCE

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FIGURES

DEFINITION OF SYMBOLS

B Length of rectangular spillway box

d Vertical depth of flow

d_n Normal depth of flow measured perpendicular to the flume slope

d_o Normal depth of flow with entrained air measured perpendicular to the flume slope

D Vertical drop from rectangular spillway crest to floor of spillway box at the bulkhead

g Acceleration due to gravity (32.2 ft./sec.^{2})

H Head on spillway crest

K Dimensionless constant in the equation for normal depth of flow with entrained air

n Roughness coefficient in the Manning formula

$$Q = \frac{1.486}{n} R^{2/3} S^{1/2} d_n W$$

q_w Water discharge per unit width of flume

Q Total water discharge

R Hydraulic radius $\dfrac{d\ W}{W + 2d}$

S Flume slope = $\sin \theta$

θ Angle between flume bottom and a horizontal line

W Width of flume

X Horizontal distance from the bulkhead to the point at which the depth is measured

Y Slope of floor of rectangular spillway box = $1/Y$

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By Fred W. Blaisdell, hydraulic engineer, and Albert N. Huff, hydraulic engineer, Division of Drainage and Water Control, Research, Soil Conservation Service

THE PROBLEM

The water-surface profile through a flume must be determined if overtopping of the sidewalls or excessively high sidewalls are to be averted.

The depth of flow at the entrance to a flume laid on a steep slope is ordinarily assumed to be equal to the critical depth.1/ This depth is then used as the starting point when computing the water-surface profile between the flume entrance and that point beyond which the depth is constant--the normal depth. In the case of many of the entrances to flumes constructed by the Soil Conservation Service, the flow conditions are such that the position of the critical depth cannot be determined within reasonable limits. For these entrances it is necessary to determine experimentally the water-surface profile at the upstream end of the flume.

Air is entrained by rapidly flowing water. The air bulks up the water and causes the actual normal depth of flow to be greater than the depth computed by the ordinarily used equations. This introduces another factor into the design of flumes laid on steep slopes.

INTRODUCTORY SUMMARY

Presented in this report are the results of nine tests made on variations of three different types of flume entrances. The findings are summarized in accompanying drawings and design charts that show, for each type of entrance:

1. Rating curves (figs. 3 and 7, pp. 7 and 13).

2. The width of flume required to handle various discharges at heads within the limits covered by the experiments (figs. 4 and 8, pp. 10 and 15).

3. Depths in the flume at several stations as a function of the discharge (figs. 5 and 9, pp. 11 and 16).

4. The depth of flow at several stations near the entrance to the flume for several heads within the range of the experiments (figs. 6, 10, and 11, pp. 12, 17, and 18).

Information on the depth of flow when air is entrained is also presented in this paper.

1/KING, H. W. Handbook of Hydraulics. Ed. 2, p. 276. New York and London. 1929.

LABORATORY FACILITIES

All of the experiments reported here were made at the St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, Minn. The apparatus used for the tests of flume entrances was constructed especially for these experiments. This apparatus is shown in figure 1, page 3.

Water was obtained from the main laboratory supply channel and conveyed to the test set-up through a 12-inch pipe. A valve in this pipe was used to control the rate of flow. A stilling chamber just upstream from the model entrances was used to quiet the water leaving the supply pipe. A short approach channel having its floor level with the crest of the flume entrances was used between the stilling chamber and the flume entrance models.

The water leaving the model flume entered a short channel containing baffles to dissipate the energy in the water and smooth out the flow. A 1.5-foot Type-H measuring flume was located at the end of this channel and used to measure the flow through the models. This measuring flume had previously been calibrated.

DESCRIPTION OF MODELS

Plans and sections of each of the three types of flume entrances on which tests were made are presented in figure 2, page 4.

The flumes and entrances were constructed of galvanized sheet metal and given a coat of aluminum paint. Piezometers were located at the points noted. Use was made of only that piezometric data obtained from the piezometers located upstream from the bulkhead. Water-surface readings obtained at the other piezometer locations were used in computing the depth of the flow in the flume.

Drawings of the U-type entrances are presented in figure 2(a). Several lengths B and depths D of the box, six combinations in all, were tested as noted in the table. The floor of the box was given two different slopes: 1 on 6 and 1 on 12. The effects of these variations in the dimensions are discussed below. All other dimensions were constant throughout the six tests.

The only difference between the two tests made on the Wisconsin type flume entrance shown in figure 2(b) is in the shape of the wingwall.

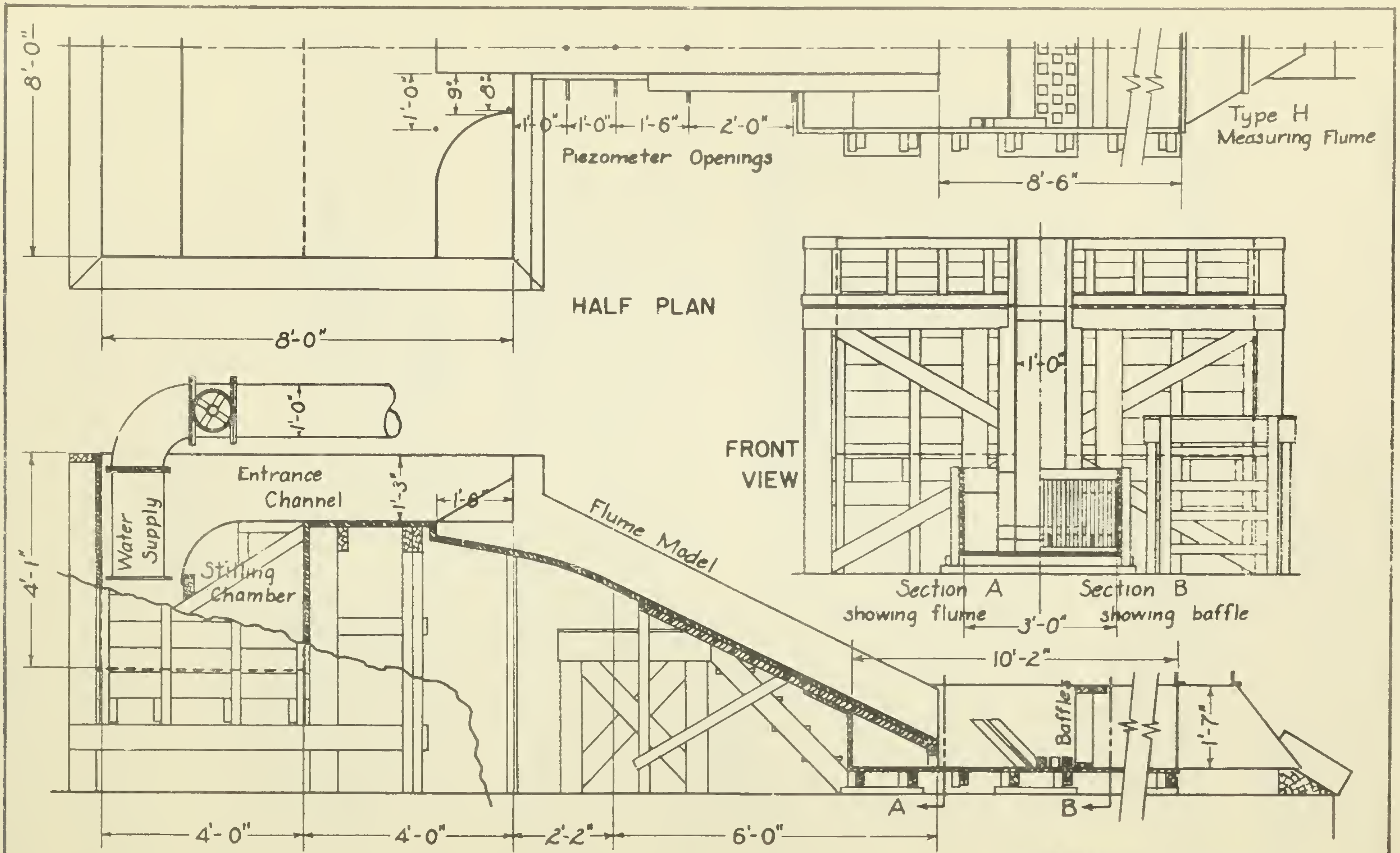
The 2:1 flume entrance shown in figure 2(c) is simple to construct. Only one test was conducted on this type of entrance.

The flume slope was 1 on 2 or 26°34' (cos. 0 = 0.894) for all tests.

TEST METHODS

In conducting each test run, the valve in the supply line was adjusted to the approximate desired rate of flow. After the flow through the flume had become constant, the two piezometers located upstream from the end of the approach channel were read to obtain the head at the flume entrance. The head in the measuring flume was also determined and the discharge computed.

Piezometers located at several points along the center and side of the flume were used in determining the water-surface profile for the first tests. When an investigation showed them to be unreliable, future depth measurements were made directly on the water surface



LABORATORY SETUP
FOR
TESTING FLUME ENTRANCES
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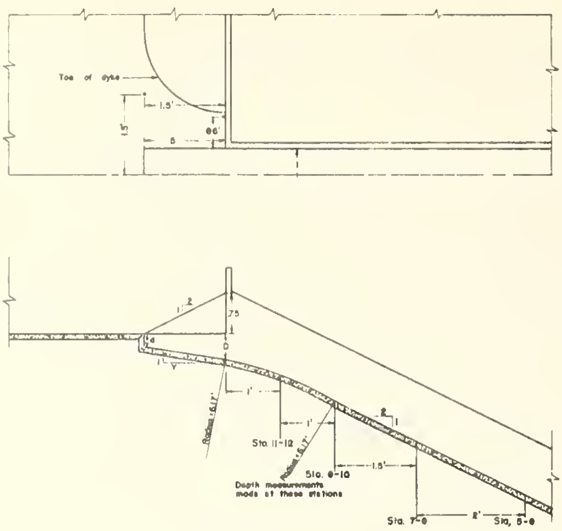
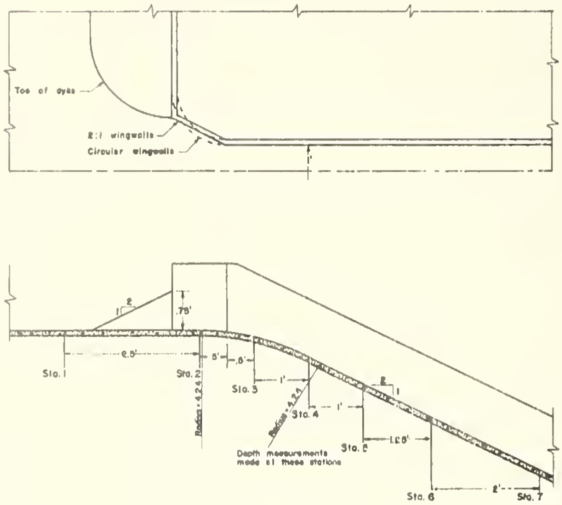
Figure 1



(a)

U-TYPE FLUME ENTRANCE

Test No.	B In.	D In.	d In.	Y
7	18	4	1	6
8	18	3	1.5	12
9	15	3	1.75	12
10	12	3	2	12
11	18	2	1.5	12
12	12	2	1	12

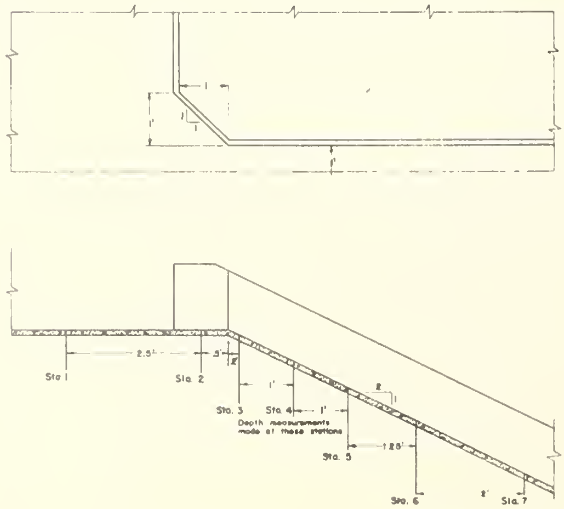


(b)

WISCONSIN TYPE FLUME ENTRANCE

Test 13 2:1 wingwalls

Test 14 Circular wingwalls



(c)

2:1 FLUME ENTRANCE

Test 15

FLUME ENTRANCES

ON WHICH TESTS WERE MADE

Figure 2

in the flume, the depths being measured vertically. Only those tests in which direct water-surface measurements were obtained were used in preparing this report.

The flow was increased from run to run until the maximum capacity of the flume entrance was reached. A sufficient number of points was obtained so that the rating curves for each station could be accurately determined.

ANALYSIS OF DATA

A summary of the experimental data will be found at the end of this report.

The first step in the analysis of the data was to plot, for each station at which depth measurements were made, the vertical depth d at the side of the flume against the discharge Q. There was considerable scatter to the data due to the difficulty involved in obtaining readings on the surface of a turbulent and rapidly flowing stream. Smooth curves were drawn to generally cover the data rather than to pass through the average of the plotted points. This procedure was adopted in order to insure that the calculated depth of flow at any station would be the maximum depth--the depth that is most important in determining the flume sidewall height. Both these curves and the plotted points are presented for each type of flume entrance (figs. 5 and 9, pp. 11 and 16).

The computed normal vertical depth $d_n/\cos\theta$ and normal vertical depth with air entrainment $d_o/\cos\theta$ curves are added to the plots for the last station at which depths were determined to show how nearly these depths coincide with the observed depth of flow. Generally it may be said that the distance to the last station at which depth measurements were obtained was insufficient to permit the flow to attain its normal depth. This is particularly true for the higher discharges. See figures 5(d) and 9(f).

Head-discharge data were plotted for each type of flume entrance, a curve drawn through the average of the plotted points, and the equation of the curve determined. See figures 3 and 7, pages 7 and 13.

It is possible to scale up the results of these tests in order to make them applicable to larger structures. To do this it is simply necessary to determine the scale ratio by computing the ratio of homologous lengths in the model and its prototype. In this analysis the width of flume W has been selected as the basic dimension to be used in determining the scale ratio and the relative dimensions of the model and prototype. According to the Froude model law used to scale up the model quantities, linear dimensions are proportional to the linear scale ratio and discharges are proportional to the five-halves power of the linear scale ratio. The model heads H were divided by the width of the flume (1 foot for the flumes tested) and the discharges were divided by the flume width raised to the five-halves power or $1^{5/2} = 1$ before plotting them in order to reduce these quantities to a unit width of flume. In order to scale up these quantities it is simply necessary to obtain the value H/W from the field measurements, enter the plot to determine $Q/W^{5/2}$, and multiply this latter value by $W^{5/2}$ to obtain the prototype discharge. These computations have been made for heads from 1 to 10 feet and for flume widths from 2 to 40 feet. They are presented in the form of charts for each of the three types of flume entrances. (See figs. 4 and 8, pp. 10 and 15.)

Curves are also presented for each type of flume entrance giving a dimensionless representation of the water-surface profile at the upper end of the flume. (See figs. 6, 10, and 11, pp. 12, 17, and 18.) The data used in plotting these curves were obtained from the plots of H vs. Q and d vs. Q. To use these curves a value of H/W is first computed. Values of

d/W and corresponding values of X/W are read from the appropriate H/W curve and multiplied by W to convert them to prototype dimensions. The d/W - X/W plots are terminated at that point at which the observed depth equals the computed normal depth of flow with air entrainment. It should be recognized that it is not possible to accurately simulate air entrainment in small scale models and that for this reason the depths measured in the models are too low. It appears advisable therefore to consider the minimum water-surface profile as coincident with the normal profile when air entrainment is present.

NORMAL DEPTH OF FLOW

The normal depth of flow d_n was computed from the Manning formula using for n a value of 0.012. While there is some doubt as to the validity of this formula and the resistance coefficients for supercritical velocities, it is common practice to use a formula of this type since at the present time nothing better is available. Also, this formula has given good results where it has been used to compute the depths for supercritical velocities.

The normal depth with air entrainment d_o was computed from the equation

$$d_o = K^{2/3} \sqrt[3]{q_w^2/g}$$

where K is a dimensionless constant and q_w is the water discharge per unit width of channel. This equation was first presented by DeLapp.2/ The value of $K^{2/3}$ used here is 0.372, the maximum average value computed by DeLapp from Hall's data.3/ The minimum value computed by DeLapp from Hall's data is 0.316. These data on air entrainment are believed to be thoroughly reliable and, in the absence of contradictory evidence, are recommended for use in flume design.

RESULTS OF TESTS

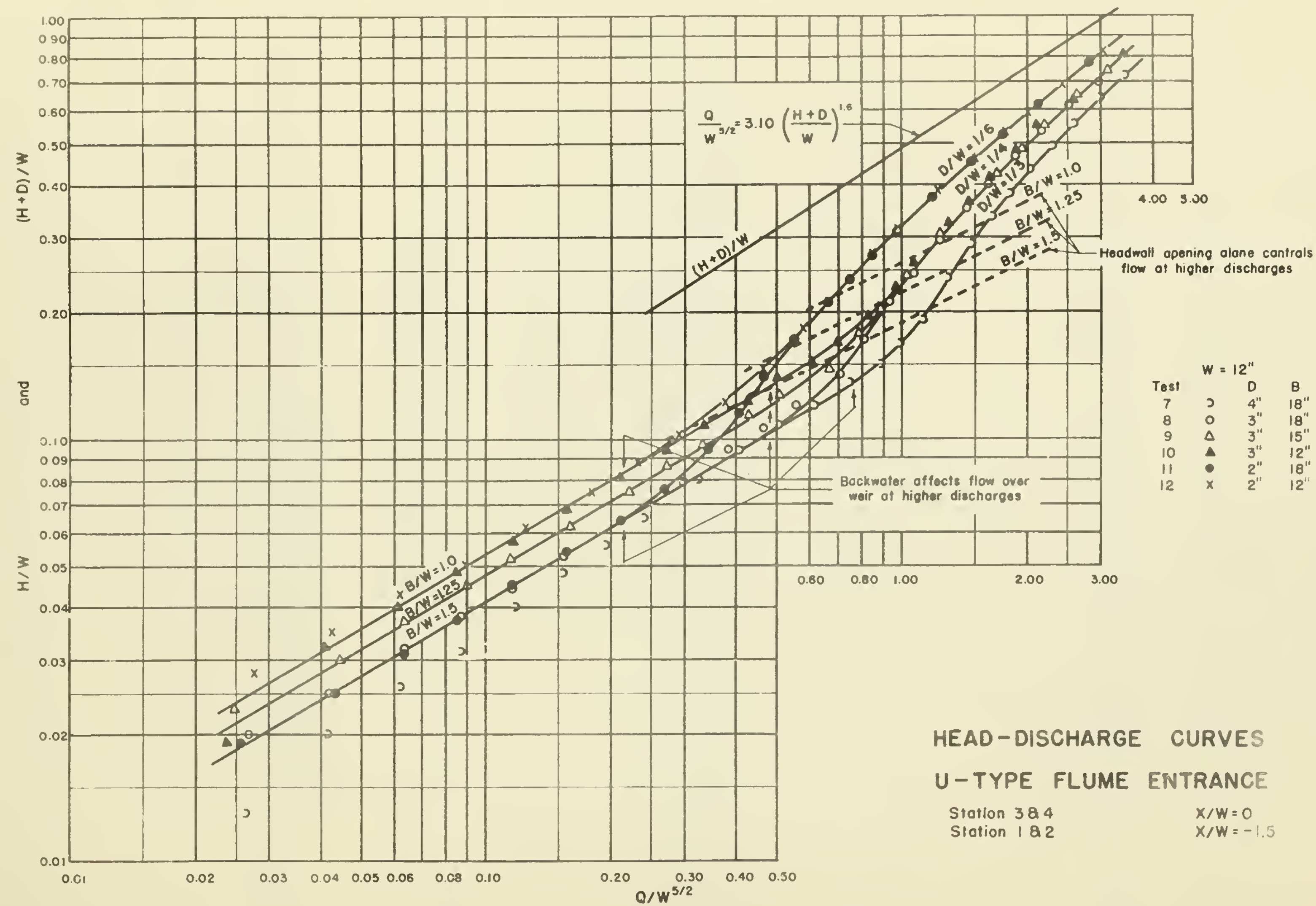
U-Type Flume Entrance

Head-discharge data for the six variations of the U-type flume entrance on which tests were made are presented in figure 3, page 7. The resulting plot may at first prove confusing, but a little study will bring out the advantages of plotting all of the data on a single sheet.

At the lower rates of flow the head-discharge relationship is a function of the length of weir crest and the three curves shown in figure 3 represent the three different crest lengths used in making the six tests. The box length B was 12 inches (B/W = 1.0) for tests 10 and 12, and it will be noted that the data plot as a single curve within the limits of experimental precision. Only one test, No. 9, was made for B = 15 inches (B/W = 1.25). Three tests, Nos. 7, 8, and 11, were made where B = 18 inches (B/W = 1.5). It will be noted that the data for test 7 deviate considerably from the curve as drawn. The method of obtaining the zero elevation of the crest for this run was unsatisfactory and was changed before succeeding runs were made. If the values of H/W are increased 0.005, the data will agree very well with that obtained for the other tests. A zero error of this magnitude is quite possible for test 7.

2/DE LAPP, W. Discussion of Entrainment of Air in Flowing Water: Open Channel Flow at High Velocities. Trans. Amer. Soc. Civ. Engin. 108: 1,448. 1943

3/HALL, L. S. Entrainment of Air in Flowing Water: Open Channel Flow at High Velocities. Trans. Amer. Soc., Civ. Engin. 108: 1,394. 1943.



HEAD-DISCHARGE CURVES

U-TYPE FLUME ENTRANCE

Station 3 & 4 X/W = 0
Station 1 & 2 X/W = −1.5

Figure 3

At the higher discharges the weir crest is flooded out and the area of the opening through the headwall determines the head-discharge relationship. The three curves obtained at the higher discharges are for three different depths of box D at the headwall. The value of D was 2 inches ($D/W = 1/6$) for tests 11 and 12; 3 inches ($D/W = 1/4$) for tests 8, 9, and 10; and 4 inches ($D/W = 1/3$) for test 7. It will be noted that the data for constant values of D/W plot along identical curves.

Between the discharge at which the weir crest begins to be flooded out and the discharge at which the headwall opening alone controls the discharge, there is a transition region where both control sections are effective.

The point at which the weir crest length ceases to control the discharge depends on the area of the headwall opening and is apparently independent of the length of the weir crest. The discharges at which the weir crest length ceases to control the flow have been noted in figure 3, page 7. The location of this point can be determined from the equation

$$Q = 7.75\, W^{1/2} D^2$$

or

$$H = 1.77 \frac{D^{5/4}}{W^{1/4}} - D.$$

The point at which the headwall opening alone begins to control the discharge is dependent on B/W and is indicated by the point of reverse curvature of the head-discharge curves. Curves have been drawn through these points of reverse curvature to indicate the point at which the opening in the headwall begins to exercise complete and independent control of the discharge. These curves have the equation

$$H = 0.524 \frac{B^{1/2} Q^{1/4}}{W^{1/8}}$$

or

$$Q \doteq 13.2 \frac{H^4 W^{1/2}}{B^2}.$$

The equations presented in this and the preceding paragraph, while they represent the data quite well, should be used with caution beyond the range of the tests from which they were developed.

All three curves in which the headwall opening controls the head-discharge relationship have been replotted to form a single curve. To accomplish this D was added to H and

plotted against the corresponding value of Q. This curve has the equation

$$\frac{Q}{W^{5/2}} = 3.10 \left(\frac{H + D}{W}\right)^{1/6}$$

or $$Q = 3.10\ W^{0.9}\ (H + D)^{1.6}$$

or $$H = 0.493\ \frac{Q^{0.625}}{W^{0.5625}} - D.$$

This equation is presented in graphical form in figure 4, page 10, for convenience. It should be noted that the lower limit of applicability of these curves has not been plotted on figure 4. However, this limit should be determined from the appropriate equations before using the plot.

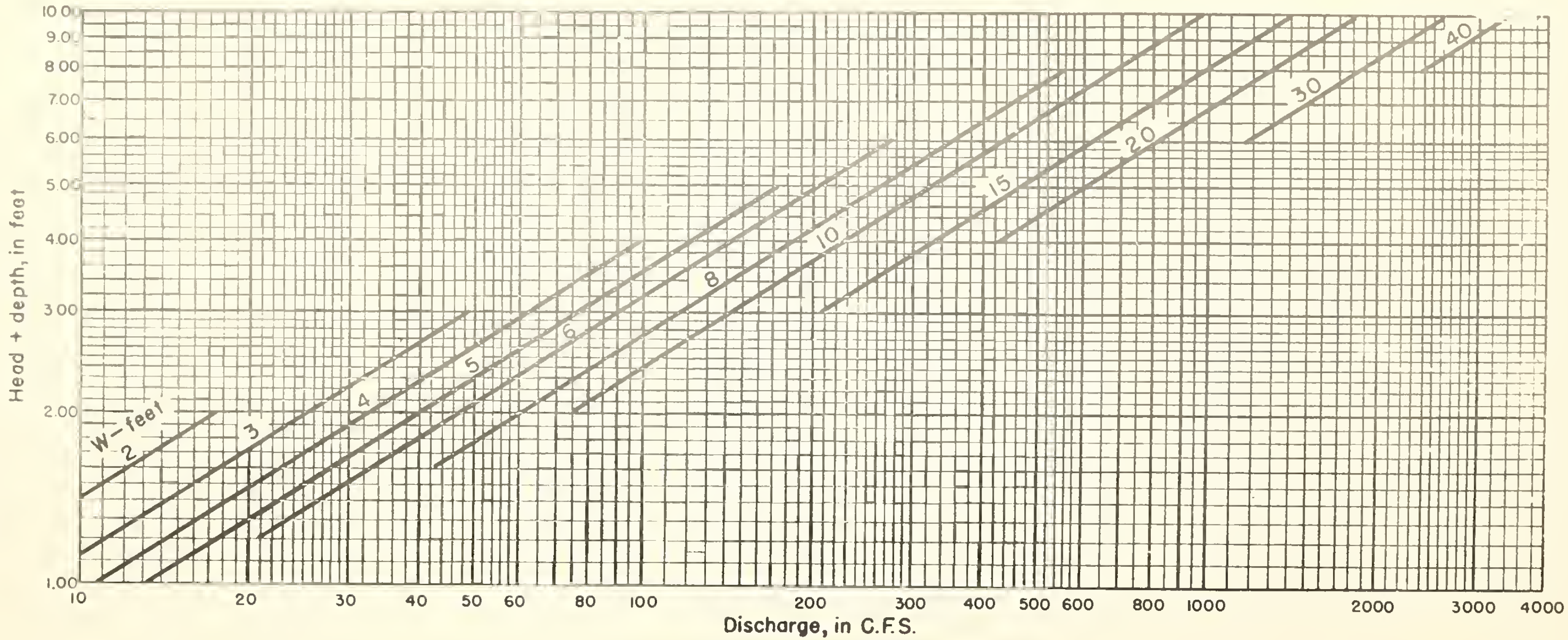
Logarithmic plots of the depth of flow in the flume against the discharge are shown in figure 5, page 11, for four stations along the flume. There is some scatter to the data due to the rough water surface and the method of obtaining the measurements. In general, however, the results appear to be quite good. Covering curves used in constructing the design charts discussed below are also shown. The covering curve used for the last station (fig. 5(d)) gives the normal depth of flow with air entrainment. Most of the points fall below this curve because the station is not far enough downstream to permit uniform flow conditions to be established. A curve giving the normal depth of flow by the Manning formula is also shown. Normal flow conditions without air entrainment had not been established for the higher discharges although they probably did exist for the lower discharges. It is to be regretted that additional depth measurements further downstream were not obtained.

The depth observations of figure 5 are plotted in the form of design charts in figure 6, page 12, for several values of the relative head. This chart is a dimensionless representation of the water-surface profile above the floor of the flume. It is valid only when the headwall opening controls the head-discharge relationship. At the left side of the chart the relative depths represent the head on the flume. At the right side of the chart the relative depths are the normal depths when air is entrained. The use of this chart has been discussed above.

Wisconsin Flume Entrance

The head-discharge data for the Wisconsin type of flume entrance is plotted in figure 7, page 13. The difference between test 13 where 2:1 wingwalls were used and test 14 where circular wingwalls were used is insignificant and a single rating curve has been drawn for the two tests. This curve has the equation

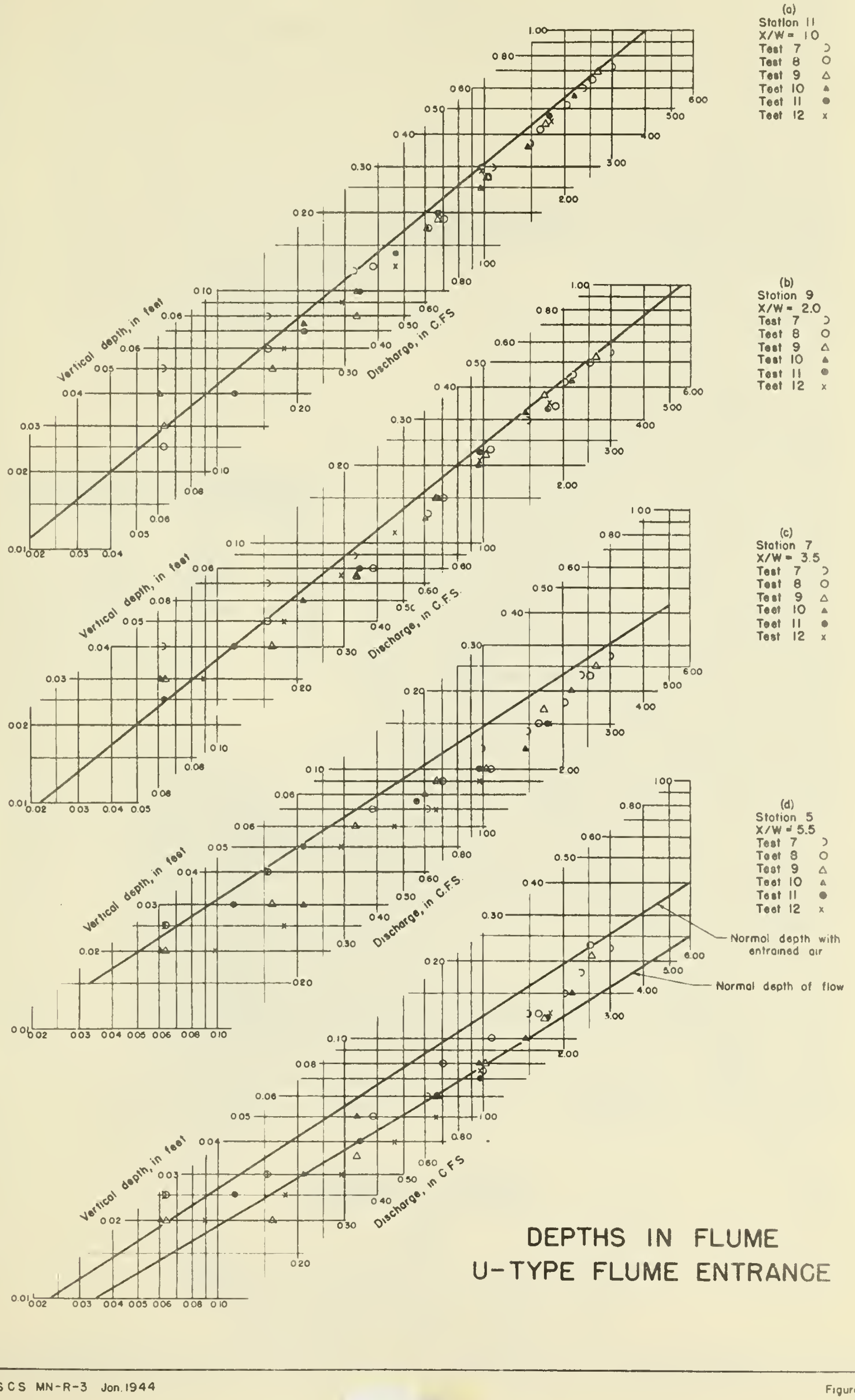
$$Q = 3.50\ W^{0.94}\ H^{1.56}$$



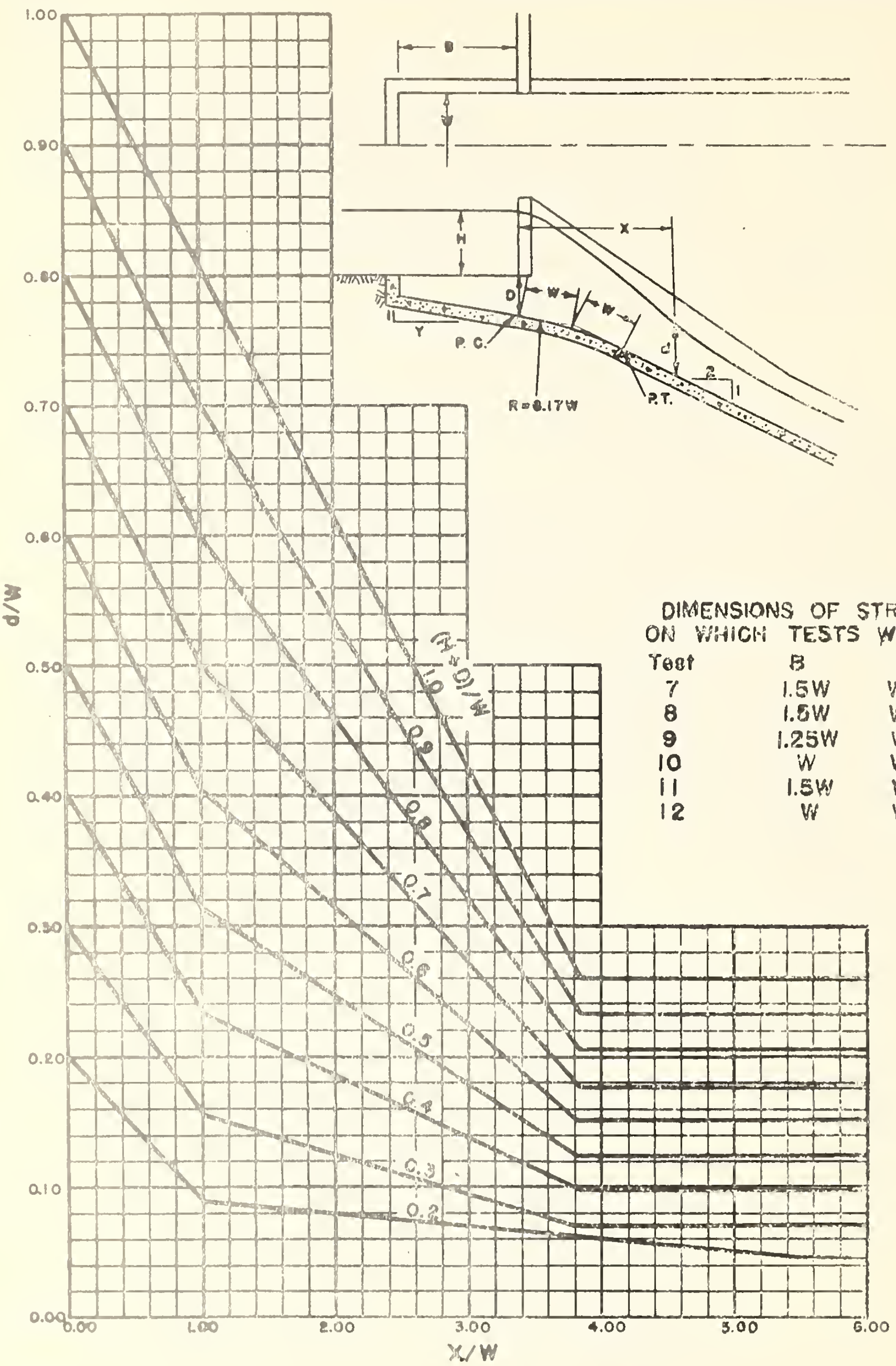
U-Type flume entrance

Caution:
These curves are valid only for
$Q \geqq 13.2\ H^4 W^{1/2}/B^2$

HEAD-DISCHARGE-WIDTH DESIGN CHART



DEPTHS IN FLUME
U-TYPE FLUME ENTRANCE



DIMENSIONS OF STRUCTURES ON WHICH TESTS WERE MADE

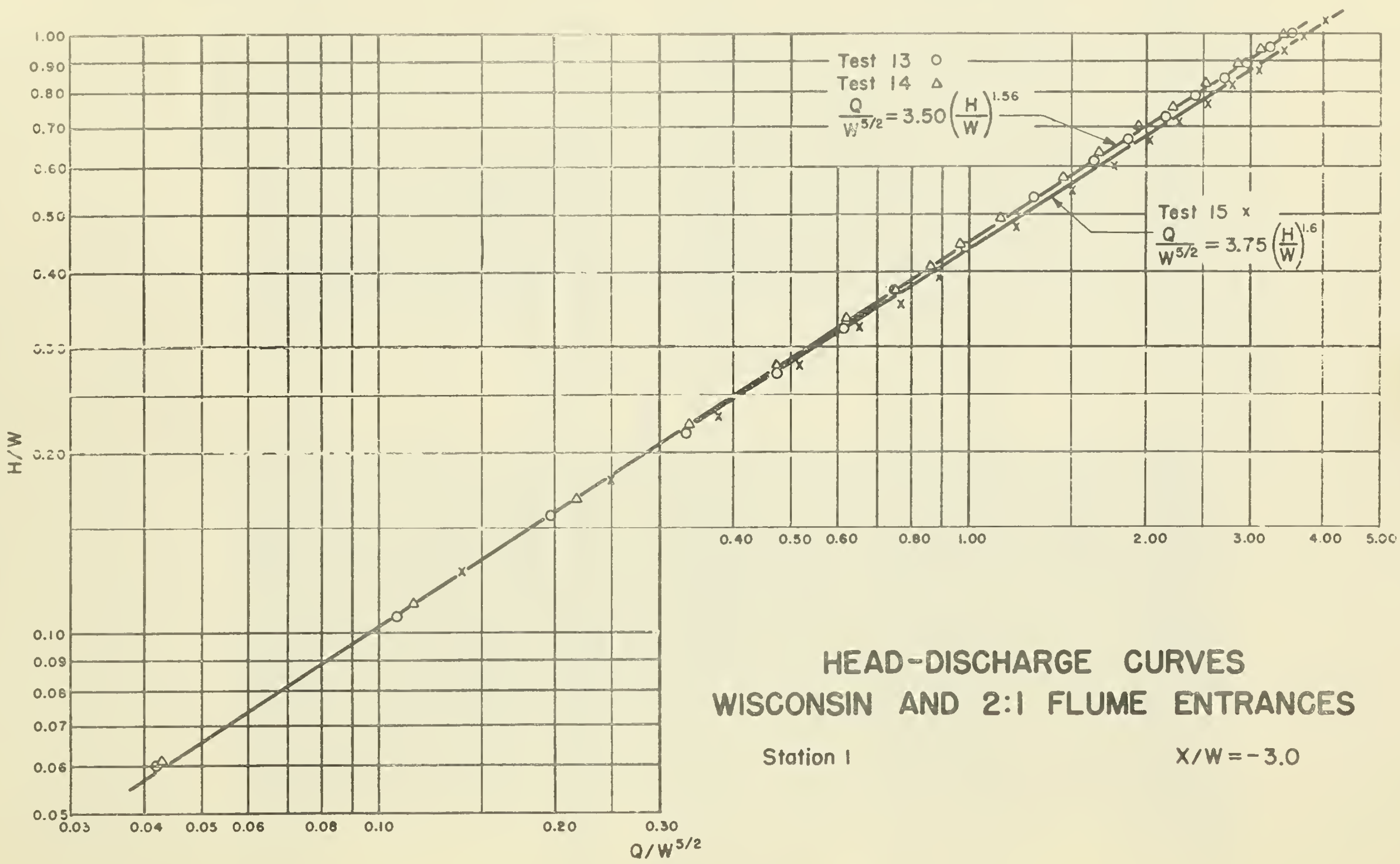
Test	B	D	Y
7	1.5W	W/3	6
8	1.5W	W/4	12
9	1.25W	W/4	12
10	W	W/4	12
11	1.5W	W/6	12
12	W	W/6	12

DESIGN CHART

FOR

DEPTH OF FLOW IN FLUME

U-TYPE FLUME ENTRANCE



HEAD-DISCHARGE CURVES
WISCONSIN AND 2:1 FLUME ENTRANCES

Station 1 $X/W = -3.0$

Figure 7

A design chart based on this equation is presented in figure 8(a), page 15.

Depths measured at six stations along the flume are plotted in figure 9, page 16. In general, the comments made for the U-type entrance also apply to these observations. The covering curves drawn for tests 13 and 14 for each station were used in preparing the design chart presented in figure 10, page 17. At station 3 standing waves caused the depths for test 13, where 2:1 wingwalls were used, to be greater than for test 14 where the wingwalls were curved. As a result, two depths of flow are shown in figure 10 for this station.

2:1 Flume Entrance

The head-discharge curve for the 2:1 flume entrance, test 15, is shown in figure 7, page 13. The fact that the curve shown does not fit the data well (the difference is about 5 percent) may be due to an error in determining the zero reading. However, the curve shown is conservative. It has the equation

$$Q = 3.75\ W^{0.9}\ H^{1.6}.$$

A chart based on this equation is presented in **figure 8(b).**

Depths of flow in the flume are shown in figure 9. The curves used in preparing the design chart (fig. 11, p. 18) are far from smooth but were drawn to fit the data.

DISCUSSION

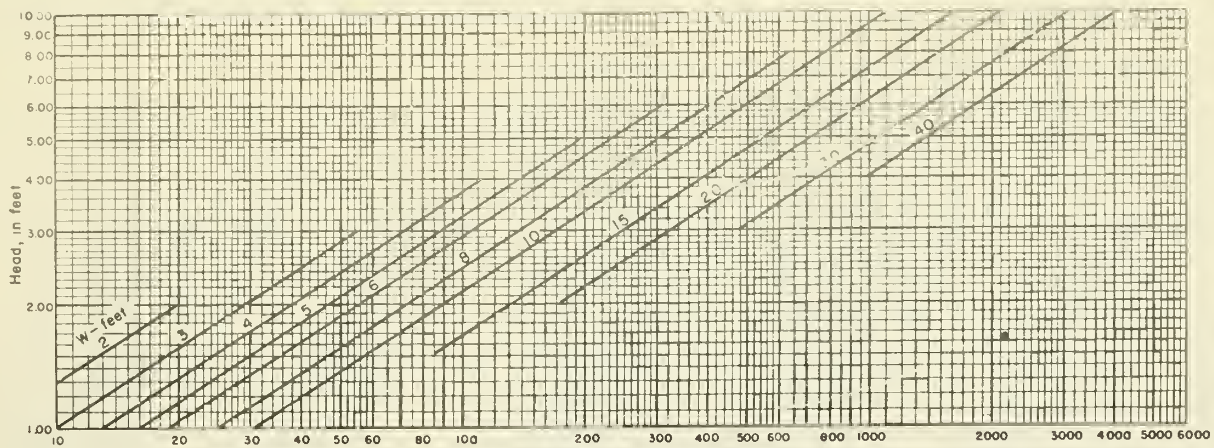
Presented in this report are the results of nine tests made on three different types of flume entrances. These results are summarized in the form of:

1. Head-discharge curves and charts, and
2. Design curves for determining the depths of flow at the upper end of the flume.

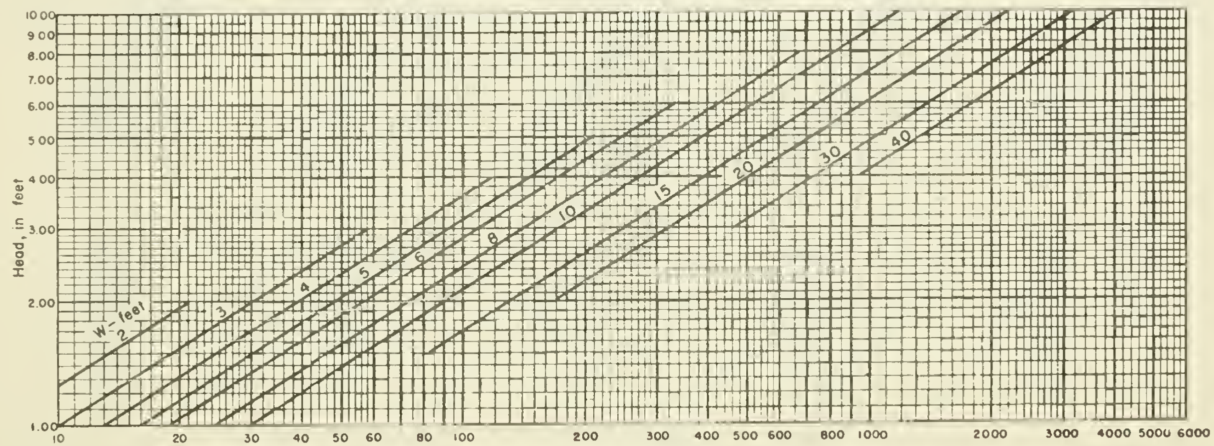
It would have been desirable to have obtained the depths at more points along the flume wall and to have extended the observations to a greater distance downstream. Also, the tests have been run on only a limited number of flume-entrance types and do not cover all of the types now in use or which might be used in the future. However, the results are presented here because, as far as is known to the writer, no other data of this type are available to the designer and there is little possibility of broadening the scope of the present work in the immediate future.

ACKNOWLEDGMENTS

The work described here was performed by the staff of the Soil Conservation Service Research Office, Minneapolis, Minn., under the direction of Albert N. Huff, formerly project supervisor. The experiments were performed at the St. Anthony Falls Hydraulic Laboratory, University of Minnesota, where the Soil Conservation Service and the Minnesota Agricultural Experiment Station are cooperating in the solution of hydraulic problems pertinent to the activities of the Soil Conservation Service.



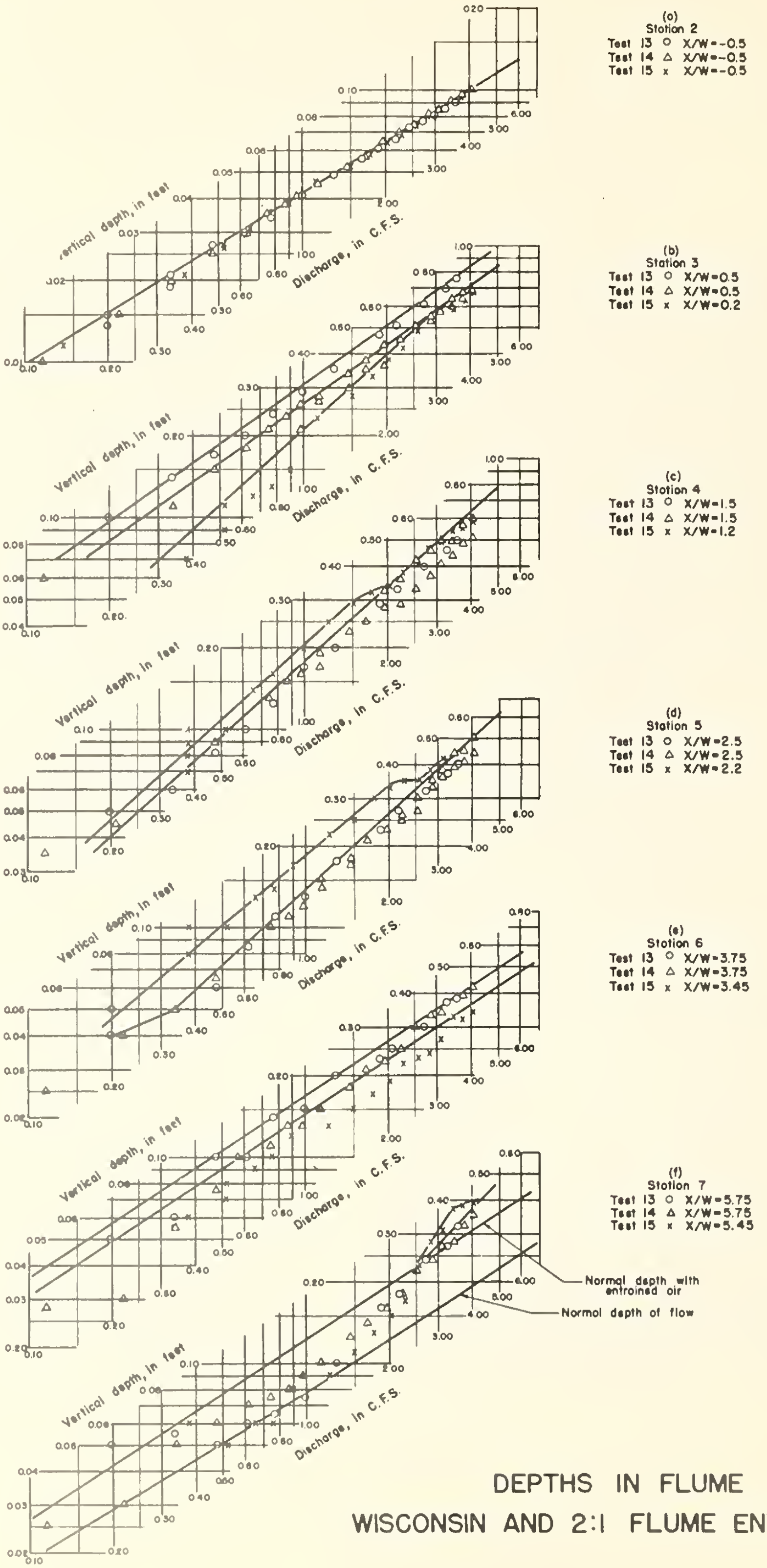
(a) Wisconsin flume entrance



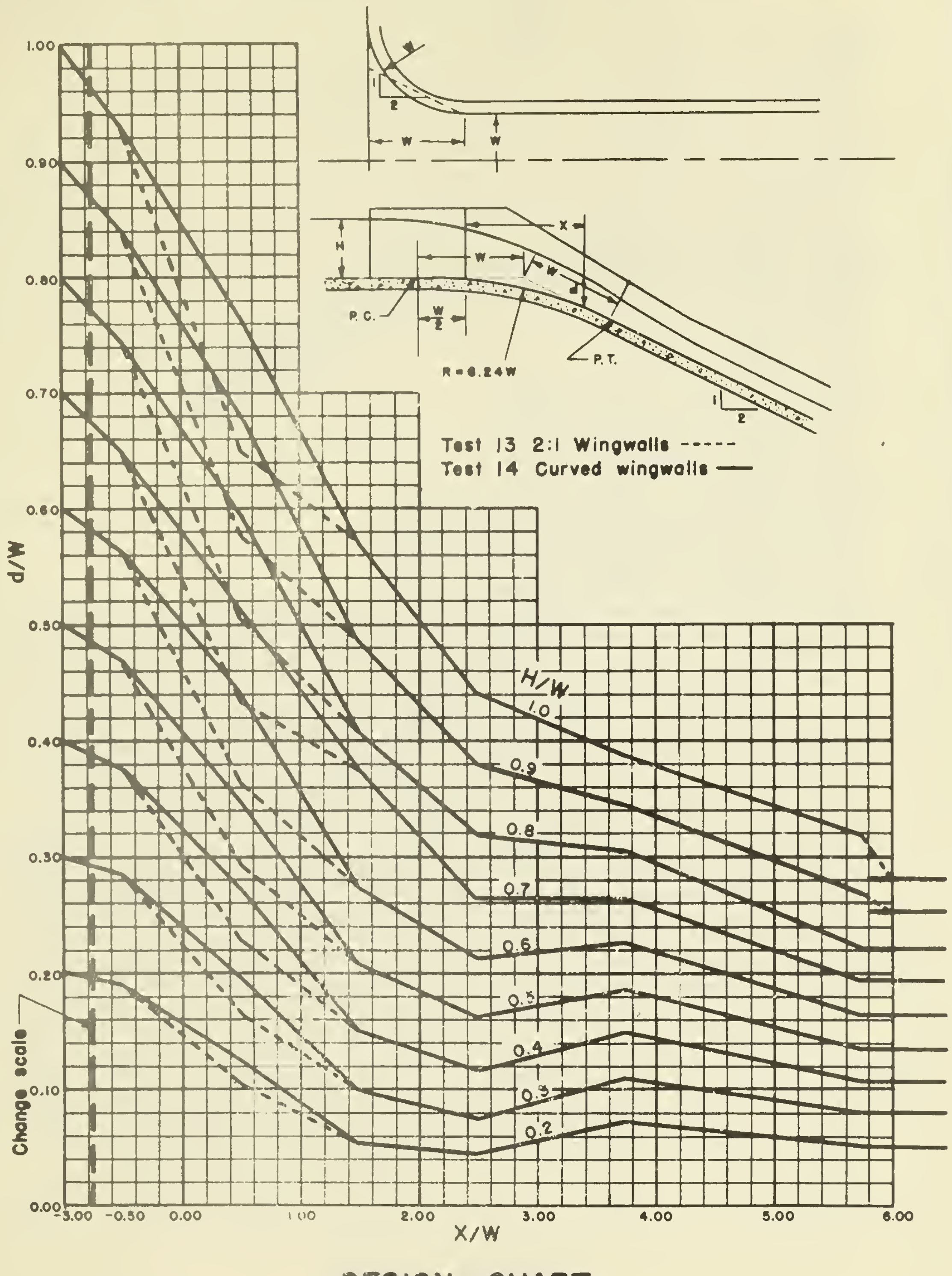
(b) 2:1 Flume entrance

HEAD-DISCHARGE-WIDTH DESIGN CHART

Figure 8



DEPTHS IN FLUME
WISCONSIN AND 2:1 FLUME ENTRANCES

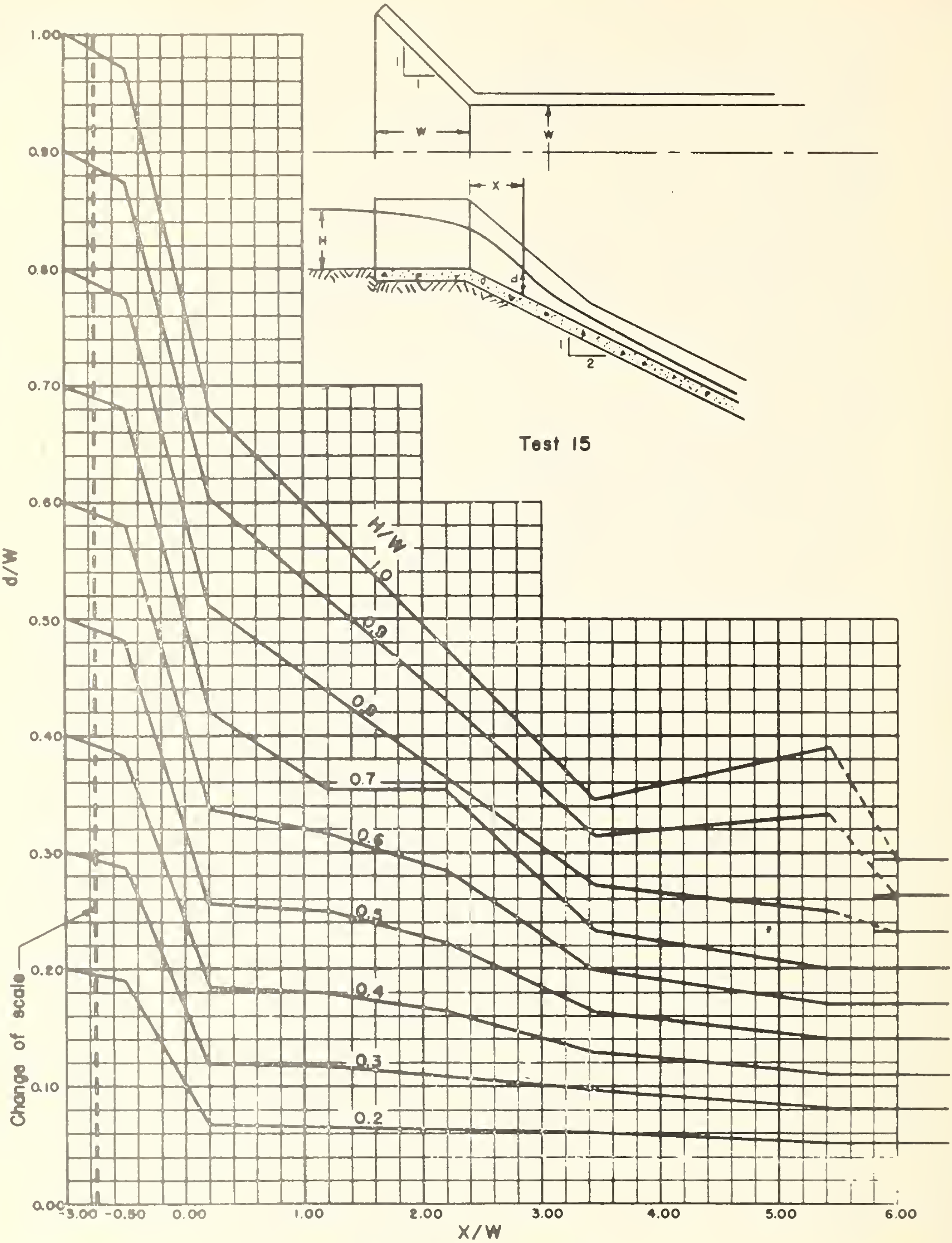


DESIGN CHART

FOR

DEPTH OF FLOW IN FLUME

WISCONSIN FLUME ENTRANCE



DESIGN CHART
FOR
DEPTH OF FLOW IN FLUME
2:1 FLUME ENTRANCE

Figure 11

APPENDIX

SUMMARY OF DATA

SUMMARY OF DATA

U-TYPE FLUME ENTRANCE

Test No. 7

Run No.	Discharge Q (c.f.s.)	Head (ft.) 1–2	Head (ft.) 3–4	Depth at side of flume (ft.) 5	7	9	11
				Piezometer Numbers			
1	0.0264	0.015	0.013				
2	.0426	.021	.020				
3	.0620	.027	.026	0.025	0.025	0.04	0.05
4	.0870	.034	.033				
5	.118	.042	.040				
6	.154	.050	.048	.03	.04	.07	.08
7	.194	.059	.056				
8	.240	.068	.065				
9	.324	.083	.080	.05	.06	.09	.12
10	.408	.097	.094				
11	.508	.111	.108				
12	.618	.125	.120	.06	.07	.13	.175
13	.747	.141	.136				
14	.887	.154	.151				
15	.991	.172	.168	.075	.12	.20	.275
16	1.12	.198	.191				
17	1.29	.241	.240				
18	1.47	.288	.291	.125	.14	.30	.37
19	1.65	.338	.338				
20	1.82	.381	.381				
21	2.03	.431	.435	.15	.18	.42	.52
22	2.31	.493	.496				
23	2.60	.554	558				
24	3.00	.642	642	.225	.275	.550	.725
25	3.43	.730	.732				
28	2.34	.501	.501	.18	.23	.45	.60

SUMMARY OF DATA

U-TYPE FLUME ENTRANCE

Test No. 8

Run No.	Discharge Q (c.f.s.)	Head (ft.) 1–2	Head (ft.) 3–4	Depth at side of flume (ft.) Piezometer Numbers 5	7	9	11
1	0.0268	0.020	0.020				
2	.0420	.025	.025				
3	.0639	.032	.032	0.025	0.025	0.03	0.025
4	.0870	.038	.038				
5	.1159	.045	.044				
6	.155	.054	.053	.03	.04	.05	.06
7	.209	.066	.063				
8	.299	.083	.079				
9	.383	.099	.094	.05	.07	.08	.125
10	.467	.112	.106				
11	.557	.126	.120				
12	.701	.150	.142	.08	.09	.15	.19
13	.819	.177	.172				
14	.937	.215	.211				
15	1.071	.250	246	.10	.10	.23	.30
16	1.243	.297	.295				
17	1.44	.353	.350				
18	1.62	.400	.400	.125	.15	.34	.42
19	1.88	.465	.466				
20	2.16	.533	.533				
21	2.54	.619	619	.23	.24	.50	.650
22	2.98	.701	.699				
23	.210	.066	.062				

SUMMARY OF DATA

U-TYPE FLUME ENTRANCE

Test No. 9

Run No.	Discharge Q (c.f.s.)	Head (ft.) 1–2	Head (ft.) 3–4	Depth at side of flume (ft.) Piezometer Numbers 5	7	9	11
1	0.0249	0.021	0.023				
2	.0446	.029	.030				
3	.0639	.036	.037	0.02	0.02	0.03	0.03
4	.0901	.045	.045				
5	.1161	.052	.052				
6	.161	.064	.062	.02	.03	.04	.05
7	.222	.077	.075				
8	.274	.089	.086				
9	.332	.102	.097	.035	.06	.075	.08
10	.430	.118	.114				
11	.510	.132	.127				
12	.669	.156	.147	.06	.09	.15	.19
13	.794	.182	.178				
14	.899	.210	.204				
15	1.032	.248	.243	.08	.10	.220	.275
16	1.243	.308	.306				
17	1.43	.354	.353				
18	1.70	.428	.426	.12	.16	.375	.44
19	1.95	.489	.487				
20	2.21	.552	.550				
21	2.66	.653	.652	.21	.250	.525	.70
22	3.14	.745	.741				

SUMMARY OF DATA

U-TYPE FLUME ENTRANCE

Test No. 10

Run No.	Discharge Q (c.f.s.)	Head (ft.)		Depth at side of flume (ft.) Piezometer Numbers			
		1–2	3–4	5	7	9	11
1	0.0237	0.022	0.024				
2	.0405	.031	.032				
3	.0614	.039	.040	0.02	0.02	0.03	0.04
4	.0847	.048	.048				
5	.1159	.057	.057				
6	.157	.068	.068				
7	.211	.082	.081	.03	.03	.06	.075
8	.272	.096	.094				
9	.335	.110	.107	.05	.06	.075	.10
10	.421	.126	.123				
11	.501	.142	.139				
12	.606	.157	.151	.05	.08	.125	.175
13	.698	.174	.169				
14	.833	.201	.195				
15	.967	.234	.229	.08	.09	.20	.25
16	1.071	.265	.261				
17	1.30	.323	.324				
18	1.45	.363	.362	.10	.12	.32	.36
19	1.64	.413	.414				
20	1.88	.477	.477				
21	2.16	.540	.539	.15	.20	.425	.56
22	2.60	.635	.632				
23	3.43	.807	.805				

SUMMARY OF DATA

U-TYPE FLUME ENTRANCE

Test No. 11

Run No.	Discharge Q (c.f.s.)	Head (ft.)		Depth at side of flume (ft.) Piezometer Numbers			
		1-2	3-4	5	7	9	11
1	0.00937	0.009	0.011				
2	.0256	.017	.019				
3	.0431	.023	.025				
4	.0633	.031	.031	0.02	0.025	0.025	0.025
5	.0855	.037	.037				
6	.1151	.045	.045	.025	.03	.04	04
7	.157	.055	.054				
8	.211	.066	.064	.03	.05	.06	.07
9	.269	.078	.076				
10	.342	.097	.094	.04	.06	.08	.10
11	.404	.118	.115				
12	.465	.142	.140	.05	.06	.11	.14
13	.550	.173	.172				
14	.664	.212	.210	.06	.075	.15	.20
15	.747	.241	.238				
16	.850	.275	.273				
17	.976	.313	.311	.07	.10	.225	.30
18	1.188	.378	.374				
19	1.47	.455	.453				
20	1.75	.525	.524	.12	.15	.33	.47
21	2.12	.621	.620				
22	2.81	.775	.774				

SUMMARY OF DATA

U-TYPE FLUME ENTRANCE

Test No. 12

Run No.	Discharge Q (c.f.s.)	Head (ft.)		Depth at side of flume (ft.)			
		Piezometer Numbers					
		1–2	3–4	5	7	9	11
1	0.0276	0.026	0.028				
2	.0426	.034	.035				
3	.0620	.042	.043				
4	.0893	.052	.051	0.02	0.02	0.03	0.04
5	.1251	.063	.062				
6	.179	.077	.075	.025	.025	.05	.06
7	.232	.091	.088				
8	.292	.105	.102	.03	.05	.075	.09
9	.378	.126	.123				
10	.465	.150	.147	.04	.06	.11	.125
11	.577	.186	.182				
12	.671	.216	.214	.05	.07	.150	.20
13	.755	.246	.243				
14	.858	.277	.276				
15	.976	.315	.317	.075	.09	.21	.29
16	1.236	.388	.390				
17	1.51	.464	.465				
18	1.78	.533	.533	.125	.15	.35	.45
19	2.01	.596	.595				
20	2.43	.693	.690				
21	3.05	.822	.822				

SUMMARY OF DATA

2:1 FLUME ENTRANCE

Test No. 15

Run No.	Discharge Q (c.f.s.)	Head (ft.) 1	2	Depth at side, center, and side of flume (ft.) Piezometer Numbers 3			4			5			6 - 6a			7 - 7a		
1	0.1385	0.127	0.115															
2	.249	.180	.162															
3	.379	.230	.207	0.07	0.16	0.07	0.09	0.09	0.07	0.10	0.05	0.08	0.06	0.04	0.06	0.06	0.06	0.06
4	.520	.280	.252	.09	.20	.11	.10	.10	.10	.10	.06	.10	.07	.05	.08	.05	.08	.05
5	.654	.323	.289	.12		.24	.14		.12	.13		.07	.09		.06	.06		.10
6	.765	.356	.319	.13		.27	.16		.14	.14		.08	.10		.07	.06		.11
7	.896	.393	.353	.15		.31	.20		.17	.17		.09	.12		.10	.08		.12
8	1.215	.478	.427	.23		.38	.25		.20	.22		.12	.13		.13	.09		.15
9	1.50	.546	.487	.28		.45	.29		.24	.25		.15	.15		.16	.11		.17
10	1.76	.603	.535	.33		.50	.32		.27	.30		.18	.17		.19	.13		.20
11	2.03	.662	.587	.38		.55	.34		.30	.33		.20	.19		.21	.15		.22
12	2.28	.711	.626	.42		.61	.38		.33	.35		.21	.22		.23	.17		.23
13	2.56	.763	.668	.48		.66	.41		.38	.35		.23	.23		.26	.23		.26
14	2.81	.821	.717	.54		.69	.47		.41	.38		.27	.24		.29	.28		.28
15	3.12	.877	.767	.58		.73	.49		.45	.42		.33	.27		.32	.31		.29
16	3.43	.939	.819	.62		.78	.54		.50	.40		.37	.33		.35	.37		.31
17	3.71	.991	.870	.65		.84	.55		.57	.42		.40	.32		.37	.38		.33
18	4.06	1.050	.916	.68		.89	.59		.61	.44		.41	.34		.36	.39		.35